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# Characterisation of machinable structural polymers in restorative dentistry

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ABSTRACT

*Objectives.* To characterise the mechanical properties of the machinable polymers Pekkton® (Cendres-Meteaux, Biel/Bienne, Switzerland), Lava Ultimate® (3MESPE, Seefeld, Germany), Vita Enamic® (Ivoclar Vivadent, Schaan, Liechtenstein) and the ceramic IPS e.Max Press® (Ivoclar Vivadent, Schaan, Liechtenstein). To determine the structural integrity of full coverage crowns fabricated from these materials.

*Methods.* The following tests were conducted: Biaxial flexural strength (BFS) using the piston on 3 balls jig (n = 10); Vickers Hardness (VH) 10 indentations per sample with 10 kg load & 20 s dwell time (n = 5); Hygroscopic Expansion Change (HEC) in artificial saliva over 68 days (n = 5). Structural Strength (SS) of teeth analogues (n = 20) restored with monolithic crowns from the four materials. Mean values and standard deviations for BFS, VH, HEC and SS tests were calculated and compared using one-way ANOVA with post-hoc Tukey's test at a level of 5% significance.

*Results.* BFS: IPS e.Max Press® (317 MPa ± 37 MPa), Pekkton® (227 MPa ± 18 MPa), Lava Ultimate® (145 MPa ± 18 MPa) and Vita Enamic® (137 MPa ± 7 MPa) with a significance between groups of $p < 0.0001$. VH: IPS e.Max Press® (5064 MPa ± 131 MPa), Vita Enamic® (1976 MPa ± 12 MPa), Lava Ultimate® (924 MPa ± 27 MPa) and Pekkton® (445MPa ± 21 MPa) with a significance between groups of $p < 0.0001$. HEC (%vol change): Pekkton® (0.14% ± 0.14%), Vita Enamic® (0.38% ± 0.16%) and Lava Ultimate® (1.06% ± 0.17%). SS for full-coverage crowns: Pekkton® (2037 N ± 49 N no fracture), IPS e.Max Press® (1497 N ± 165 N), Lava Ultimate® (1476 N ± 142 N) and Vita Enamic® (1127 N ± 108 N).

*Significance.* The properties investigated suggest that full coverage monolithic PEKK crowns possess adequate mechanical and physical properties for use in the posterior region of the mouth. These results must be considered alongside other data including clinical studies.



## 1. Introduction

The advent of CAD/CAM in restorative dentistry has increased the range of fabrication technologies beyond polymerisation, casting and porcelain-densification by sintering. Until recently, the focus of CAD/CAM has been on machinable ceramics [1], as polymers were considered to have inferior structural properties making them less desirable restorative materials with unpredictable long-term performance [2].

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We are now presented with a new generation of machinable polymers that include highly cross-linked resin based composites (HCL-RBCs) and Resin Infiltrated Ceramics (RICs) such as Lava Ultimate® (3MESPE, Seefeld, Germany) and Vita Enamic® (Ivoclar Vivadent, Schaan, Liechtenstein). These materials represent a new approach increasing the range of treatment options in restorative dentistry [3,4]. An exciting further addition to these groups is the Polyaryletherketones (PAEKs).

PAEKs are a relatively new family of semi-crystalline thermoplastic polymers with high temperature stability and high mechanical strength [5]. They consist of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups [5]. Two commercially available PAEKs used for dental applications (Fig. 1) are polyetheretherketone; PEEK (Bredent GmbH & Co. KG, Senden, Germany; Evonik Industries, Essen, Germany; Juvora Ltd. Thornton Cleveleys, Lancashire, UK) and polyetherketoneketone; PEKK (Pekkton®, Cendres-Meteaux, Biel/Bienne, Switzerland).

The biocompatibility of the PAEK family was confirmed three decades ago [6] and further studies have supported their long-term biocompatibility [7–9]. Applications of PAEKs in dentistry that are being explored include implant superstructure for fixed arch bridgework and resin-based composite veneered substructure for bridges [10–12]. However, PAEK materials may also offer potential benefits in the provision of full-coverage monolithic dental crowns. PEEK has had more coverage in the literature, however there are very few studies that support the application of PEKK in restorative dentistry [13–16] and there are no independent studies investigating the application of PEKK as a monolithic unveneered restoration.

This work aims to characterise and compare the mechanical properties of all three materials (HLC-RBCs, RICs and PEKK) to determine the applicability of PEKK (PEKKTON®, Cendres-Meteaux, Biel/Bienne, Switzerland) as a material for the provision of a monolithic crown in posterior load-bearing teeth. In line with the current guidance from the Academy of Dental Materials for the testing of properties dental materials, this study aims to characterise these materials by measuring the Biaxial flexural strength (BFS), Vickers Hardness (VH) and the Hygroscopic Expansion Change (HEC) [17]. The Structural Strength (SS) of teeth restored with a full coverage crown for each of the three materials was also tested. Wear performance of PEKK was not included in this suite of characterisation tests, as this has been characterised previously [16]. The dental literature is guarded about the true value of in-vitro wear testing as the data obtained is often derived from systems that lack qualification, validation and reproducibility. Moreover, as simulators and wear methods differ greatly in their mode of operation, it is not possible to compare the results; which in turn limits the estimation of true clinical performance [17].

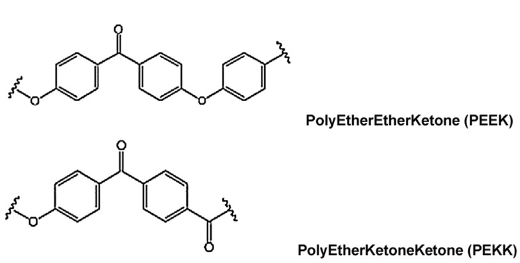


**Fig. 1 – Chemical structure of PEEK & PEKK.**

## 2. Materials and methods

### 2.1. *Sample preparation of polymeric materials for biaxial flexural strength, vickers hardness and hygroscopic expansion experiments*

The materials tested were Pekkton® (LOT 200368), Vita Enamic® (LOT 40501) and Lava Ultimate® (LOT 720957). For the biaxial flexural strength (BFS) and Vickers Hardness (VH), sixty specimens were prepared from the three test materials (n = 20) with ten samples used for each test. For the hygroscopic expansion change test (HEC), twenty-one specimens were prepared for the three test materials (n = 7).

The specimens for the BFS and VH tests were discs produced in accordance with ISO 6872:2008. These were produced by core drilling a block of machinable material (disc or ingot) using a 14 mm diamond core drill. The resulting cylinders were subsequently sectioned into four discs using a precision saw IsoMet 1000 (Buehler, USA) and finished with 35 μm-grit and 18.3 μm-grit SiC paper on a grinder/polisher Buehler Metaserv (Buehler UK ltd, UK). The final thickness of each specimen was measured over three equidistant points and averaged. The resulting disc specimens were 14 mm diameter with a mean thickness 1.13 mm ± 0.02 mm.

The specimens for the HEC tests were discs 12 mm diameter × 1 mm height. These were produced by core drilling a block of machinable material (disc or ingot) using a 12 mm diamond core drill. The resulting cylinders were subsequently sectioned into discs and polished in the same manner as that described above for the BFS and VH tests. The resulting disc specimens were 12 mm diameter with a mean thickness 1.08 mm ± 0.05 mm.

### 2.2. *Sample preparation of ceramics for biaxial flexural strength, & vickers hardness*

For the biaxial flexural strength (BFS) and Vickers Hardness (VH), twenty specimens were prepared (n = 20) with ten samples used for each test. Ceramic discs were made from IPS e.max Press ingots using a ceramic furnace Programat EP 3000 (Ivoclar-Vivadent, Germany) following the firing cycle recommended by the manufacturer. Further grinding and polishing using the same methodology described above was used to obtain the final specimens.

### 2.3. *Replica teeth preparation for structural strength experiment*

Forty identical tooth replicas (N = 40) were made from a polyurethane-based die material (AlphaDie® MF, Schütz Dental GmbH, Rosbach, Germany). A lower first permanent molar tooth (Frasaco, GmbH, Tettnang, Germany) was prepared with an occlusal reduction of 2 mm and 1 mm cervical margin chamfered finish using a 12° taper. This provided a master die that was duplicated 40 times using a silicone mould (Provil Novo Putty, Heraeus Kulzer, Germany) into which the